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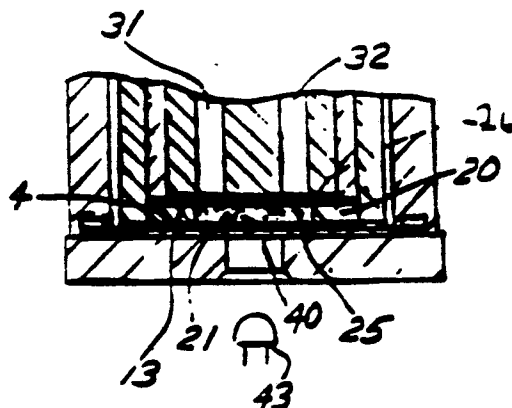
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(54) Title: CELL ASSAY DEVICE

**(57) Abstract**

This invention encompasses porous microchambers which contain cells and permit liquid to flow in and out of the chamber while retaining cells within the chamber. These porous microchambers serve as disposable devices for placing cells in a micro flow chamber so that properties of the cells within the porous microchamber can be measured.

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### CELL ASSAY DEVICE

This is a continuation-in-part of pending application Serial No. 07/532,571, filed June 4, 1990.

### BACKGROUND OF THE INVENTION

#### 5 Field of the Invention

This invention is in the field of microphysiometers and, in particular, it relates to single-use disposable devices and reagents, and reusable peripheral parts, used in conjunction with a microphysiometer.

#### Description of the Prior Art

10 The prior art describes cups which have a filter membrane on the bottom and such cups are usable for filtering and grouping cells on the inner surface of the membrane ("Selected Methods in Cellular Immunology", Edited by Barbara B. Mishell and Stanley M. Shiigi, University of California, Berkeley, Editorial Consultants: Claudia Henry and Robert I. Mishell, University of  
15 California, Berkeley, Published by W. H. Freeman and Company, San Francisco, Copyright 1980, pp. 37, 40, 43, 61, 62, 63 and 64). Also of interest are silicon electrodes for use in microflow cells described in U.S. Patents Nos 4,591,550; 4,737,464; 4,741,619; 4,704,353 and 4,519,890. These patents are incorporated herein by reference.

20 Also, see U.S. Patent No. 4,172,770 (Semersky) which describes a flow system and Japanese Patent 1002-060-A which also describes a flow system.

Further prior art takes the form of commercially-available single use vessels for the culture of living cells. In general, because of the extreme sensitivity of living cells to the chemical and physical nature of their environment,  
25 including potential problems of contamination by endotoxin microorganism or by cleaning solutions, it is preferable to use culture vessels that have been manufactured under carefully controlled conditions and then thrown away rather than cleaned and recycled. Although commercially-available single-use vessels take many forms, including bottles, tubes, and single or multiwell covered dishes, the  
30 closest commercially-available prior art items are all essentially manufactured versions of the design described in the first reference given in the previous paragraph (specifically pages 61, 62, 63, 64 of that reference). Manufacturers of such items include Costar Corp., Cambridge, MA, (product name: Transwell) and Millipore Corp., Bedford, MA, (product name: Millicell). This device is further  
35 described in EPA 239,697.

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Brief Description of the Drawings

Figure 1 is a cross-sectional schematic of components of the device of example 1;

Figure 1a is a cross-sectional schematic of the microflowchamber;

5        Figure 2 is a cross-sectional view of the device showing the spring loading mechanism;

Figure 2a is a cut-away top plan view of 2;

Figure 2b is a bottom plan view 2;

Figure 3 is a cross-sectional view showing integral spacer means;

10       Figure 3a is a cross-sectional view showing integral spacer means;

Figure 4 is a schematic of a bacterial indicator device;

Figure 4a is a capsule of porous membrane material containing cells;

Figure 5 is the effect of carbonyl cyanide m-nitrophenylhydrazine (CCCP) on 3T3 cells;

15       Figure 6 shows the effects of ethanol on P388D-1 cells; and

Figure 7 shows continuous monitoring of adherent and non-adherent cells;

Figure 8 is a plot of acidification rates verses time for P388D-1 cells in a discontinuous collagen matrix;

20       Figure 9 is a semilog plot of acidification rates verses time;

Figure 10 shows a three pronged cup which serves as an outer sleeve;

Figure 11 shows a cell focusing insert which fits into the cup of Figure 10 or 1;

Figure 12 shows graphs of focusing experiment in fibrinogen; and

25       Figure 13 shows graphs of focusing experiment in chopped collagen.

Summary of the Invention

This invention encompasses porous microchambers of which at least part of the chamber wall is constructed from a porous material such that fluids and agents contained therein can enter the porous microchamber when placed in a flowing stream, but cells cannot escape.

30       One embodiment of the invention provides for convenient assembly (or closure) of the microchamber, containing cells of choice, prior to use in the microphysiometer. In this embodiment, rigid inner and outer sleeves covered at one end with a porous membrane, together with spacer means, are fitted together

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such that when the inner sleeve is fully inserted in the outer sleeve, the membranes are separated by a spacer means. Thus, the spacer means and the inner and outer membrane form a microchamber having living cells trapped within. The sleeves are adapted for holding the microchamber containing the cells adjacent to a silicon electrode that forms one wall of a flat microflowchamber. Cells are retained within the internal cavity of the porous microchamber while liquid is permitted to flow through, above, between, and below the membranes and around the cells. (See Figure 1). The principal direction of flow of the liquid is parallel to the plane of the membranes and the silicon surface. Changes in the media surrounding the cells (such as pH changes) can be measured by the silicon electrode. Design objectives include (a) maximizing cell volume/medium volume ratio to increase measurement sensitivity, (b) optimizing exchange rate of flowing liquid to flush out spent medium and/or introduce reagents, (c) minimizing the distance that measurable species such as protons must diffuse to reach the silicon electrode. The device of this invention provides a convenient disposable reagent for use in a microphysiometer of the type described in United States Serial No. 07/408,896, assigned to the same assignee as this application and incorporated herein by reference.

In another embodiment of the invention, certain cells, such as bacterial endospores, would be trapped between two membrane discs that are welded or stuck together at their edges to form a preassembled package that could be dropped into a microphysiometer flow chamber. Use of such a device would include, but not be limited to, validation of sterilization procedures; the preassembled endospore package would be used as a biological indicator (BI) included in a load of items to be sterilized. In a further improvement of the BI for use in the microphysiometer, feed and waste lines would be firmly attached to the endospore package, as well as filters to prevent entry of contaminating micro-organisms from the feed line and the waste line exit. Thus, cells encapsulated in porous material to form a porous microchamber can be placed in the microflowchamber and advantageously studied in accord with this invention.

#### Detailed Description of the Invention

Several embodiments of this invention are described with reference to Figure 1. In its simplest embodiment outer sleeve 1 has an upper opening 2 and a lower opening 3 which is covered with porous membrane 4. An inner sleeve 10 has an upper opening 11 and a lower opening 12 which is covered with a

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porous membrane 13. Inner sleeve 10 fits within outer sleeve 1. A spacer means 20, in this instance a piece of plastic sheet material which defines an opening 21, fits into the outer sleeve. The spacer means has a thickness of about 25 to 200 micrometers, preferably about 50 micrometers, and holds the cells within about 10-300 micrometers from the silicon electrode. The height of the microflowchamber is about 50-300 micrometers. These sizes permit detection in pH change of about 0.1 to 0.5 pH units over about 1 to 5 minutes. Typical flow rates are about 10 to 200 microliters per minute. Thus, when the inner sleeve is inserted into the outer sleeve membranes 13 and 4 and the spacer means define a porous microchamber 25 in Figure 1a. In operation a plunger 30 is inserted into the inner sleeve. Plunger 30 has an inlet 31 and an outlet 32 and when the plunger is tightly pressed against the membrane 13 a seal is formed by ridge 33 or, alternatively, an O-ring sealed in a gland at the same position on the plunger. Liquid can flow from the inlet in 31 above, through, between, and below membranes 13 and 4 and the through outlet 32. A silicon sensor of the type described in U.S. Patents Nos. 4,519,550, 4,737,464, 4,741,619, 4,704,353 and 4,519,890 is adjacent and parallel to the outer surface of membrane 4 so that changes in the solution caused by the cells, such as pH, can be detected by the sensor 40. After measurement the inner and outer sleeve containing the cells can be discarded.

In one embodiment spontaneously adhering cells are placed on the inner surface of membrane 4. In another embodiment the cells are deposited in a polymer matrix, such as a collagen sponge, in the opening 21 of the spacer means. The cells in the polymer matrix are then incorporated into the porous microchamber 25. This embodiment is primarily used with cells that do not spontaneously adhere to porous membranes. While in the embodiment illustrated in Figure 1 the spacer means is a separately inserted disk, the spacer means can also be integral with the inner and outer sleeve. In a third embodiment, a mixture of non-adherent cells and a preparation of discontinuous matrix such as particles of collagen sponge with diameters typically 10-10000 times that of the cells they are to entrap, are co-centrifuged into the outer sleeve before insertion of the inner sleeve to form the chamber.

The porous membranes are made of biocompatible porous polymer material. A preferred material is a porous polycarbonate membrane. The pore size of this membrane can be selected for use with different cells. For example, a small pore size (0.45 micron or less) is suitable for use with bacteria, while a

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larger pore size (generally in the range 3-12 micron) is chosen for eukaryotic cells.

The inner and outer sleeve may have a variety of shapes, for example, they may be circular, oval, square or rectangular. A preferred shape because of flow pattern considerations is oval. The inner sleeve may fit quite loosely into the outer sleeve or, preferably the inner sleeve and the outer sleeve should have spacing element such as 14 in the form of bumps or ridges either on the outer diameter of the inner or on the inner diameter of the outer sleeve to accurately position one sleeve with respect to the other but allowing fluid to press between the sleeves. The sleeves are generally made of rigid polymer material such as polystyrene. It is important that the outer and inner sleeves in combination are specifically structured to bring the microchamber and, in particular, the outer surface of the membrane of the outer sleeve in intimate contact with the detecting electrode. It is also important that the plunger, together with the plunger ridge 33 or O-ring and the spacer means form a seal to provide a leak tight compartment defining the microflowchamber 26 so that solution can be flowed in and out of the microflowchamber 26 by way of inlet 31 and outlet 32. Thus, the silicon electrode surface 40 forms one wall of the microflowchamber 26 and the bottom surface of the plunger 34 forms the top surface of the microflowchamber 26 within which a porous microchamber containing cells is removably placed. The microflowchamber 26 has dimensions of between 10 nanoliters and 10 microliters. Although for certain applications in which analysis of effluent from the chamber is desired and cells are trapped by a polymer matrix, larger volumes may be preferable as long as the cell larger volume/flow chamber volume can be kept high enough to attain sufficient pH change rate for measurement. The plunger is made of rigid, polymer materials and is spring loaded to ensure a seal on the outer edges of the membranes. The inner and outer sleeves and the spacer with or without the cell trapping polymer matrix are intended to be disposable items.

Figure 2 illustrates a spring loading mechanism for maintaining the plunger in a position to form and seal the microflowchamber. The flow chamber casing 50 receives the outer sleeve 1. The inner sleeve 10 fits within the outer sleeve 1 and the plunger 30 fits within the inner sleeve 10 sufficiently loosely that air readily exits from between the pieces when they are being positioned. Tubing 31 and 32 deliver solution through the plunger to and from the microflowchamber 26. Spring 51 is attached to the top 52 of the plunger and the plunger retainer

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53. The plunger retainer means 53 has an opening 54 for retaining the plunger in the down position by engaging post 55. A top view is shown in Figure 2a. Figure 2b shows a bottom plate 60 and silicon electrode 40. Hole 61 provides for locking plate 60 to the flow chamber casing 50.

5                Figure 10 shows an advantageous outer sleeve 90 with prongs 91 to support the sleeve portion 92. Membrane 4 is shown at the bottom of the sleeve 92. Figure 10a is a top plan view of the device and Figure 10b is an AA sectional view. Figure 10c is a bottom plan view showing the outer surface of membrane 4 which rest against the electrode. Turning plunger retainer 53 counter  
10               clockwise releases the plunger retainer and the plunger can be removed.

              It is also advantageous to focus the cells in the center of the outer membrane. This can be done by placing the focusing insert 80 of Figure 11 into the outer sleeve 1 so that the bottom surface 81 rests on membrane 4 and cells 83 are located in the opening 82 so that only part of membrane 4 has cells  
15               located on it. The cells are centrifuged on to the membrane and the insert 80 is removed from the outer sleeve. This serves to focus cells on a smaller area of the membrane. Figure 12 and 13 illustrate how 1/5 to 1/10 the number of cells can give comparable results when the cells are focused to 1/10 the area of membrane 4. Typically cells are focused in an area 5 to 15 mm<sup>2</sup>, preferably  
20               about 10 mm<sup>2</sup>, centered over the interrogated circular area of the silicon sensing device, an area of about 5 mm<sup>2</sup>. The focusing insert 80 can be placed in the sleeve 1 of Figure 1 or sleeve 92 of Figure 10.

              Figure 3, and 3a illustrate other types of integral spacer means. In Figure 3 an integrally molded spacer 16 is on the bottom opening inner sleeve 10 before membrane 13. In Figure 3a the spacer 17 is integrally molded on the  
25               bottom opening of sleeve 1 with membrane 4 on the outside of 17 and membrane 13 on sleeve 10 on the inside of the spacer. Cells are placed on the inner surface of the membrane 4 of the outer sleeve 1 and the spacer 20 is inserted in the outer sleeve. The inner sleeve 16 is inserted to press against the spacer 20.  
30               The plunger 30 is pressed into the inner sleeve to form a seal between the spacer and the membranes and define microflowchamber 26. The membrane 4 rests on the silicon electrode 40 and fluid is pumped over the cells. Various cell affecting agents are contained in the fluid and the effects of those agents on the cells is measured by silicon electrode 40. The small volume of the microflowchamber  
35               provides for extremely sensitive or responsive measurements.



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Figure 4 illustrates details of a porous microchamber intended for use as a Biological Indicator. In Figure 4 spores 61 are trapped between upper 60 and lower 70 porous membranes and a feed line or inlet 62 with in-line filter 63 and a waste line or outlet 64 with in-line filter 65. The filter prevents bacteria from entering the microchamber 66 and is made from a material such as nitrocellulose or polycarbonate mesh material having pore size of 0.2 - 0.45 microns, typically. In this embodiment liquid can be flowed through feed line 62 through the microchamber 66 and out the waste line.

Endospores are typically of the genus Bacillus, such as Bacillus Subtilis, ATCC #9372, subspecies niger. Figure 4a illustrates a capsule of porous material 75 containing cells 76. This porous capsule fits in the microflowchamber. The invention is further illustrated by the following examples.

Example 1: Effects of Exogenous Cell-Affecting Agent on the Metabolism of Adherent Cells in a Single Use Cell Assay Device as Measured with the Microphysiometer

Adherent cells, sometimes referred to as anchorage-dependent cells, generally must be attached to a biocompatible surface in order to maintain stable metabolic rates and increase in numbers. Adherent cell lines have been used for a wide variety of studies, including toxicological, pharmacological and environmental applications. In order to study whether adherent cells could be used in a single use cell assay device designed for the microphysiometer, the following procedure was performed. Outer sleeves 1 were placed in a 12-well tissue culture plate and Dulbecco's modification of Eagles medium (DME) containing 5% fetal bovine serum was added to the wells to 50% of capacity. The sleeves were seeded with mouse fibroblast 3T3 cells (an adherent cell line) and the entire plate was incubated at 37°C in 5% CO<sub>2</sub> for 2 or more days. During this time the cells settled to the bottom of the sleeves and attached to the porous membranes, whereupon they were allowed to grow to approximately 70% confluency. At that time each outer sleeve was removed from the plate and spacer means 20 and inner sleeve 10 were placed on top of the layer of living cells. This entire assembly was then placed inside the flow chamber casing 50.

It was important during assembly to prevent air bubbles from being introduced into the flow chamber. This is accomplished by the following means: (1) a small amount of medium must be present on top of the silicon electrode 40 so that when sleeve 1 is placed on top no air is trapped between the two

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surfaces; (2) a small amount of medium must be present on top of the layer of cells and the spacer means on top of membrane 4, and membrane 13 must be dry before inserting the inner sleeve 10 into outer sleeve 1 --care must be taken to visually ensure that there are no bubbles trapped between the membranes or below the bottom membrane 4; (3) the inlet line 31 must be filled with medium and a small drop of medium should suspend under the plunger surface 34 before introduction of the plunger assembly into the inner sleeve. Additional components were assembled as described in the text and shown in Figures 1 and 2, and the whole placed within the microphysiometer and maintained at 37°C. DME without bicarbonate (having a buffer capacity of approximately 2mM) was then perfused into the chamber and acidification rates were measured periodically as described by Parce et al. (*Science* 246, 243 (1989)). During the indicated period the DME was supplemented with the metabolic uncoupler carbonyl cyanide *m*-nitrophenylhydrazine (CCCP; 5 micromolar  $\mu$ M). The rate of medium acidification increased while the cells were exposed and then returned to the original acidification rate after replacement of the CCCP-containing perfusion medium with the original medium (See Figure 5).

Example 2: Immobilization and Monitoring of the Metabolism of Non-adherent Cells in a Continuous Polymer Matrix

Non-adherent cells (also known as anchorage-independent cells) generally do not become anchored to adjacent surfaces. Nevertheless, it may be desirable to use a microphysiometer to monitor the metabolism of some of these types of cells for toxicological, pharmacological, environmental, etc., purposes. In initial experiments in which non-adherent cells were trapped between two membranes as described in Example 1, reproducible acidification was not observed and subsequent studies revealed that the cells were swept to the sides of the porous microchamber away from the central detector by the movement of fluid through this volume. In order to prevent this loss of non-adherent cells due to movement of fluid, some restriction of cell movement was deemed necessary.

A number of biocompatible sponge-like materials have been made commercially available for use as hemostatic agents. These materials, include, but are not limited to, collagen, polyvinyl alcohol and polyurethane. When applied to a surgical wound, these materials promote the deposition of new tissue. The tortuous network and proven biocompatible nature of these materials might allow them to serve as cell immobilization matrices, and thus some of these materials

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were tested for their ability to immobilize non-adherent cells within the microphysiometer. To accomplish this, a spacer means 20 was placed within an outer sleeve 1 containing a  $5\ \mu$  pore polycarbonate membrane. Into the center hole of the spacer means a 6 mm diameter disk of polymer matrix, approximately  
5 150  $\mu$ m thick, was placed. The outer sleeve 1 and polymer matrix were placed within a well of a 12-well microtiter plate. For experiments with mammalian cells, a spacer means 20 was inserted in the outer sleeve prior to addition of the polymer matrix. One ml of a suspension containing either P388D-1 cells (non-adherent mammalian cells; approximately  $10^7$  cells/ml) or *Saccharomyces*  
10 *cerevisiae* (non-adherent yeast cells; approximately  $10^7$  cells/ml) was pipetted into the outer sleeve. The microplate was then centrifuged at  $400 \times g$  for 5 min., after which an inner sleeve 10 was placed within the outer sleeve and thus a second membrane was located above the cells trapped within the polymer matrix. The inner and outer sleeves, spacer means (when present), polymer matrix and  
15 cells were inserted into the flow chamber casing 50 and acidification rates of the cells were determined as described in Example 1. With the mammalian cell line stable metabolic rates were achieved for the duration of the experiment. In the yeast experiment the rates of acidification determined with the microphysiometer increased with time, indicating an increase in cell number within the  
20 microflowchamber for the duration of the experiment. Both of these experiments suggest that the cells were properly immobilized and their metabolism not adversely affected by the immobilization procedure or the microphysiometer environment.

25 Example 3: Effects of Ethanol on the Metabolism of a Population of Non-adherent Cells

P388D-1 cells were centrifuged into a polymer matrix and their metabolism monitored with a microphysiometer as described in Example 2. After a period of adjustment to the microphysiometer environment during which time the rates of acidification of the cells' environments stabilized, the DME with 5% fetal bovine serum was replaced with DME containing 5% fetal bovine serum and  
30 10% ethanol for a period of 5 min. Following the exposure to this potentially harmful formulation, the medium lacking ethanol was reintroduced into the microphysiometer and used to flush out the ethanol-containing medium. The metabolism of the P388D-1 cells was continuously monitored during the medium  
35 exchange. As can be seen in Figure 6, this concentration of ethanol suppressed

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the metabolism of the cells, and this effect was not reversed by the removal of ethanol from the perfusion medium, suggesting that irreversible damage may have been done to the cells immobilized in the microphysiometer.

Example 4: Long-term Continuous Monitoring of Both Adherent and Non-Adherent Cell Metabolism

Non-adherent (P388D-1) and adherent (NRK) cells were placed in each of two disposable cell assay devices in the manners described in Examples 1 and 2 and placed within each of two cell chambers in a microphysiometer. The respective acidification rates of the two populations were measured for a period of over 12 hours while DME containing 5% fetal bovine serum was perfused through the cell chambers. Figure 7 represents a plot of the acidification rates of these cell populations, both of which demonstrated stable rates for the duration of the experiment. The non-adherent cell population required a period of adjustment to the microphysiometer environment (approximately 2.5 h), during which the acidification rate for this population increased rapidly. This was followed by a long period of less dramatic increase in the rate of acidification, said state occurring for the remainder of the experiment.

Example 5: Immobilization of Non-adherent Cells and Continuous Monitoring of Metabolism in a Discontinuous Matrix

A polymer matrix which would form around non-adherent cells and thus immobilize them would eliminate the need to manufacture and position disks of precast polymer matrix. In order to test this concept, the procedure described in Example 2 was performed with the following modification. No precast polymer matrix was inserted into the spacer means 20. A collagen hemostatic sponge (Collastat, Vitaphore Corp., Chicago, Ill.) was suspended in phosphate-buffered saline solution pH 7.2) and finely chopped in a blender for six 3 sec. cycles. A volume (0.5 ml) of this suspension, which consisted of particles of collagen matrix of various sizes, mostly in the range of 0.2 to 1.0 mm diameter and representing about 0.5% (v/v) of the suspension, was mixed with 0.5 ml of a P388D-1 cell suspension (approximately  $10^7$  cells/ml). The cell/polymer suspension was centrifuged at 400 x g for 5 min. into the outer sleeve 1 with a spacer means 20; an inner sleeve 10 was added and this assembly was inserted into the flow chamber casing 50. The metabolism of the cells as indicated by the rate at which they acidified their environment was monitored as described in

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Example 1. After a period of acclimation to the microphysiometer environment, stable rates of acidification were measured for the duration of the experiment (Figure 8). These results demonstrate that the discontinuous matrix used in this experiment did immobilize the non-adherent cells and that cellular metabolism was apparently not adversely affected by this procedure. Such a discontinuous matrix preparation may thus be appropriate for determining the effects of cell-affecting agents as described in Example 3.

Example 6: Monitoring of Bacterial Growth and Metabolism in a Microphysiometer

In order to measure the rate of acidification of the microflowchamber environment by a bacterial population, a number of modifications to the experimental and single-use element design described in Example 1 were made. A suspension of *Bacillus subtilis* endospores which had been enumerated with a Petroff-Hauser direct counting chamber was centrifuged into an outer sleeve 1 with a spacer means 20. The suspension had been diluted to a density so that approximately 250 endospores would be present in the microflowchamber when the microflowchamber was completely assembled. No polymer matrix was present, the lower membrane 4 had a pore size of 0.4 micron and the membrane above the endospores 13 had a pore size of 0.22 micron. Instead of DME with 5% fetal bovine serum, a complex bacteriological nutrient medium was substituted and the cells were incubated at 37°C in the microphysiometer. This example provides evidence that the invention has utility in the field of validation of desterilization procedures when used as a biological indicator. No discernible metabolic rate could be observed until approximately four hours after the experiment began, after which a rapid increase in acidification was seen. From a semi-log plot of these rates a determination of the doubling time of *B. subtilis* in the microphysiometer could be determined (Figure 9).

Example 7: Concentrating Cells into the Reading Area of the Microphysiometer Cell Capsule Using a "Cell Focusing" Device and Immobilization of Cells using a Fibrin Gel

When the standard cell loading procedure is used for loading cells into the cell capsule,  $\sim 1 \times 10^6$  cells (TF-1, bone marrow cells) must be used to have acidification rates of  $\sim 100 \mu\text{V}/\text{sec}$  (medium buffer 1 mM). The large number of cells are required because they are deposited over the entire membrane area

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(113 mm<sup>2</sup>) during the cell loading. The actual reading area is much less, ~5 mm<sup>2</sup>.

In order to decrease the cell number required to obtain equivalent rates which are necessary to obtain optimum precision of acidification rate measurement, we have designed a "cell focuser" which is a plastic insert that directs cells during the loading procedure into a small area in the middle of the cell capsule membrane. It is shaped like a cylinder so that cells are evenly distributed in the circular area at the base of the focuser, and the top is shaped like a funnel to allow a larger volume of cells to be used if necessary to reach the required cell loading numbers (Figure 11). There is a ridge on the outer edge of the top portion of the focuser which rests on the upper edge of the cell capsule to support the device during cell loading, and the barrel of the focuser extending down into the cell capsule is of the appropriate length to contact and press against the bottom membrane. The cells are deposited in a circular area of 11.4 mm<sup>2</sup>.

Cell capsules with spacer in a 12 well titre plate are filled with 0.7 ml of loading medium, and the cell focuser is placed in the capsule well, aligning it in the center. The 0.1 to 0.2 ml of cell suspension containing 100,000 - 200,000 cells is placed in the cell focuser. The assembly is then placed into a well containing 2 ml of loading medium. The plate is then centrifuged at 500 x g for 5 min. at room temperature. The cell focuser is carefully removed from the capsule using a forceps, and the cells are overlaid with 50 µL of fibrinogen/thrombin mixed reagent. The fibrinogen/thrombin reagent is prepared immediately before use by mixing equal volumes of purified fibrinogen (microliter mg/ml, dissolved in RPMI 1640 culture medium containing 10 mg/ml human serum albumin and 1% D-glucose) solution with purified thrombin solution (~0.8 NIH units/ml, dissolved in RPMI 1640). All reagents are endotoxin free. After the fibrin gel is hardened, ~5 min., the membrane insert is sunk down over the entrapped cells. The capsule is then assembled into the microphysiometer.

When cells are loaded using the cell focuser, they adhere sufficiently to the membrane so that they are not remixed when the focuser is removed. The fibrin gel overlaying the cells in the circular pattern holds the cells tightly into place, and there is no cell movement when observed under the microscope using a flow rate of 100 µL per min. This procedure was also successfully done using chopped collagen, by precoating the bottom membrane with a carpet of chopped collagen according to standard procedures. Figure 12 shows the stimulation of TF-1 cells by GM-CSF using the standard fibrin gel entrapment procedure (1 x 10<sup>6</sup>

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cells) and the cell focuser with 1/5th the cell number ( $2 \times 10^5$  cells). Equivalent results were obtained, and the cell focuser gave 34% higher rates. Figure 13 shows the same experiment done with chopped collagen. Again, equivalent results were obtained, and the cell focuser rates were the same as the standard method.

- 5           Using the cell focuser, it is possible to get equivalent results to the standard method with 1/5 to 1/10 the number of cells (100,000 to 200,000) cells. This is very important when cells are difficult to grow as in primary cell cultures. A calcium alginate gel is suitable to fix the cells.

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What is claimed is:

- 5           1. A device for removably placing cells in a microflowchamber having a volume of about 10 nanoliters to about 10 microliters of a microphysiometer comprising a porous microchamber which contains cells and retains cells within the microchamber when liquids flow in and out of the microchamber wherein the porous microchamber comprises inner and outer porous membranes separated by a spacer means which is about 25 to 200 micrometers thick.
- 10           2. A device for removably placing cells in a microflowchamber having a volume of about 10 nanoliters to about 10 microliters of a microphysiometer comprising a porous microchamber which contains cells and retains cells within the microchamber when liquids flow in and out of the microchamber wherein the porous microchamber comprises a capsule of porous membrane material.
- 15           3. A device according to claim 2 with inlet and outlet flow lines directly attached to the porous microchamber whereby liquid is flowed through the inlet flow line into the porous microchamber to contact the cells in the porous microchamber and out of the porous microchamber through the outlet flow line.
- 20           4. In combination the porous microchamber of claims 1, 2, or 3 within a microflowchamber having:
  - (a) a means for flowing liquid in and out of the microflowchamber and
  - (b) a means for detecting changes in properties of the liquid within the microflowchamber.
- 25           5. The combination of claim 4 wherein the height of the microflowchamber is about 50 to 300 micrometers.
6. The combination of claim 4 wherein the cells are held about 10 micrometers to about 300 micrometers from a silicon electrode by the porous microchamber.



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7. A device for removably placing cells in a microflowchamber of a microphysiometer having a volume of about 10 nanoliters to 10 microliters comprising:

- 5 (a) an outer sleeve having a top and bottom opening wherein the bottom opening is covered with a porous membrane;
- (b) an inner sleeve fitting within the outer sleeve and having a top and bottom opening wherein the bottom opening is covered with a porous membrane; and
- 10 (c) a spacer means having a thickness of about 25 to 200 micrometers between the porous membranes of the inner and outer sleeves which defines an opening and which together with the porous membranes defines a porous microchamber when the inner sleeve is placed within the outer sleeve and both porous membranes are in contact
- 15 with the spacer means and wherein cells are maintained in the porous microchamber when liquid flows through the porous membranes.

8. A device according to claim 7 wherein the spacer means is a continuous strip of thin plastic material fitting the inner wall of the outer sleeve,

20 defining an opening and having a thickness of about 25 to 200 micrometers.

9. A device according to claim 7 wherein the spacer means is integral with the outer or inner sleeve.

10. A device according to claims 8 or 9 wherein the height of the microflowchamber is about 50 micrometers to about 300 micrometers.

25 11. A device according to claim 7 wherein the cells are held about 10 to about 300 micrometers from a silicon electrode by the porous microchamber.

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12. A device according to claim 7 wherein cells are focused on a portion of the membrane in the outer sleeve.

13. A device according to claim 7 wherein the opening defined by the spacer means is covered with a polymer mesh which entraps cells.

5           14. A device according to claim 13 wherein the polymer mesh is a collagen sponge.

15. A device according to claim 7 wherein non-adherent cells are fixed in a fibrin gel.

10           16. A device according to claim 14 wherein the cells to be tested are intermixed with polymer matrix particles and cocentrifuged on the porous membrane of the outer sleeve before inserting the inner sleeve.

17. A device according to claim 16 wherein the polymer matrix particles are particles of collagen sponge.

15           18. In combination with the device of claim 7, a plunger with a top and bottom surface which has openings for directing a stream of liquid through the plunger and which fits into the inner sleeve and the bottom surface of the plunger contacts the porous membrane of the inner sleeve; a silicon electrode which contacts the outer surface of the porous membrane of the outer sleeve wherein when the plunger is pressed a seal is formed between the porous  
20           membranes, the spacer means, the plunger and the silicon electrode to define a microflowchamber where liquids are flowed into and out of the microflowchamber having a volume of about 10 nanoliters to about 10 microliters through the openings in the plunger.

25           19. A device according to claim 7 wherein the inner and outer sleeve is separated by a spacing element.

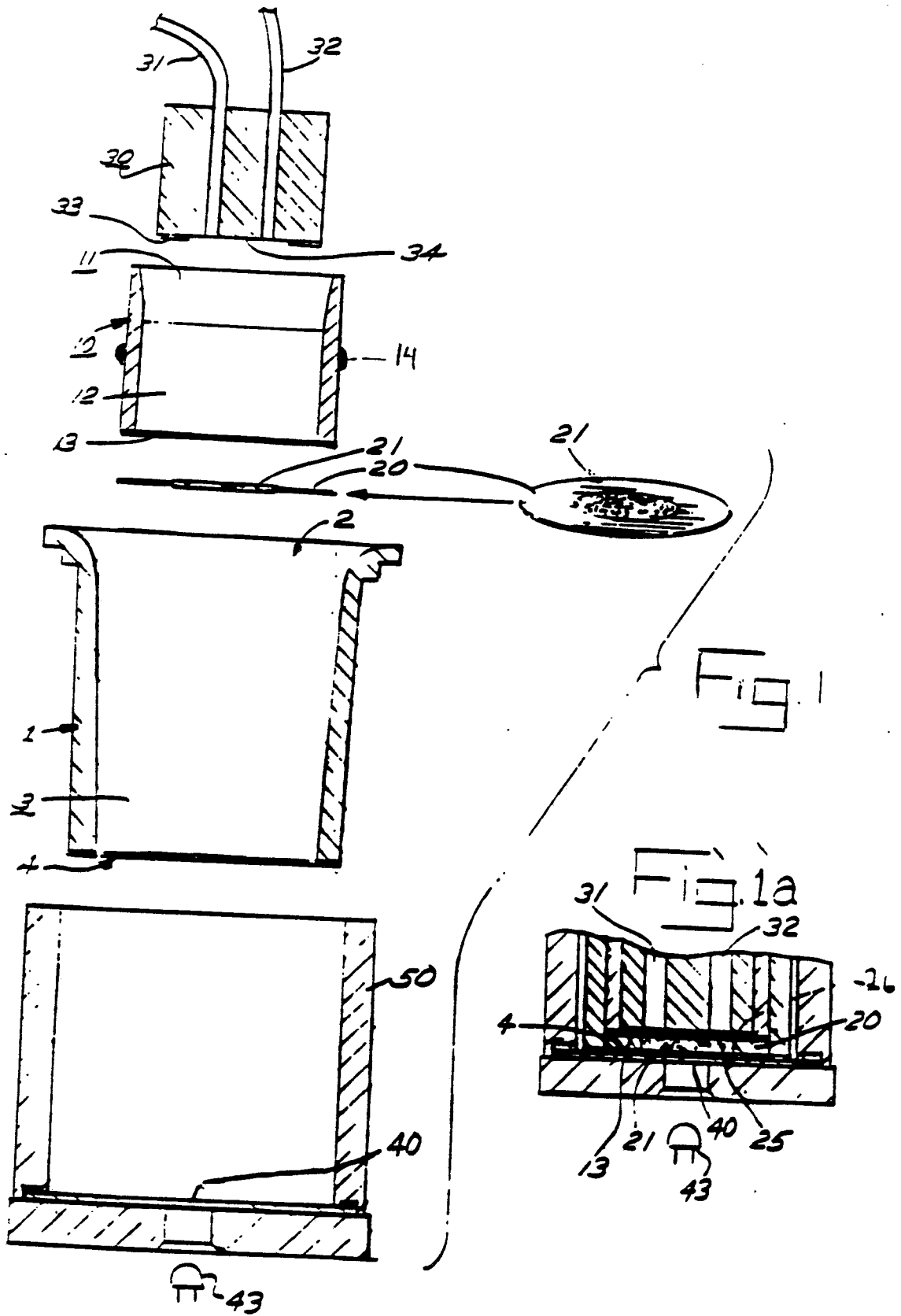


Fig. 2a

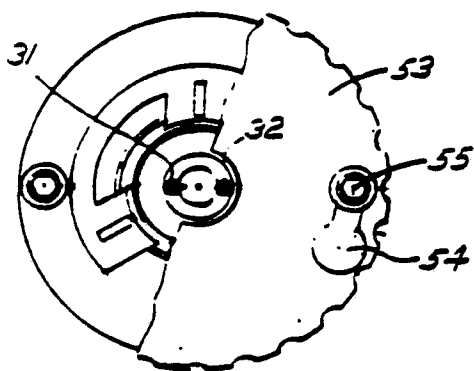


Fig. 2

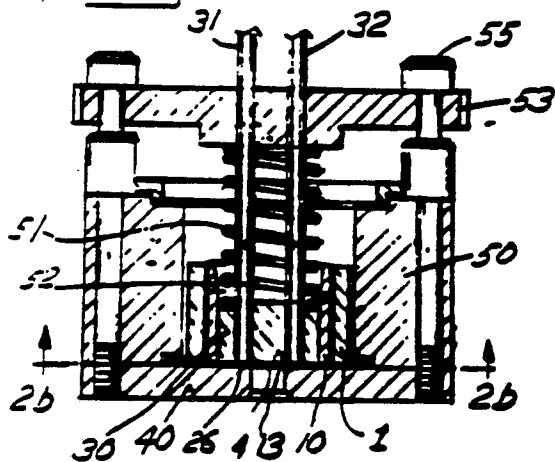


Fig. 2b

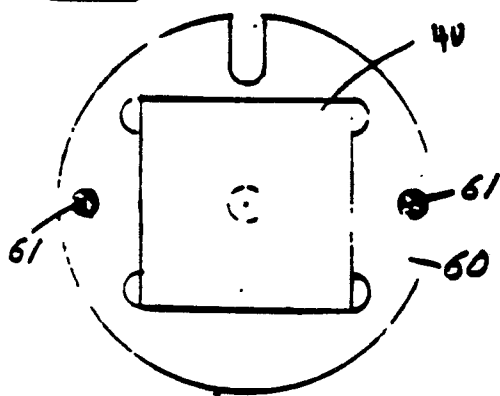


Fig. 3

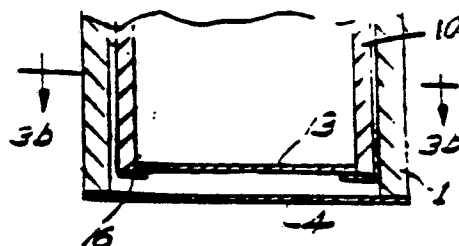


Fig. 3a

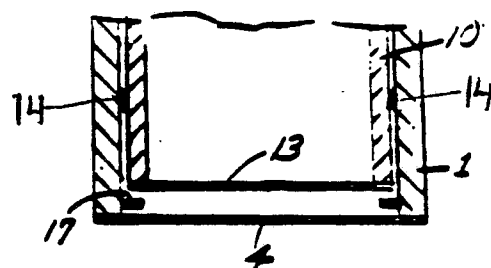
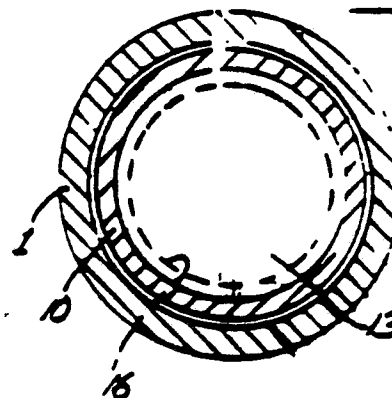


Fig. 3b



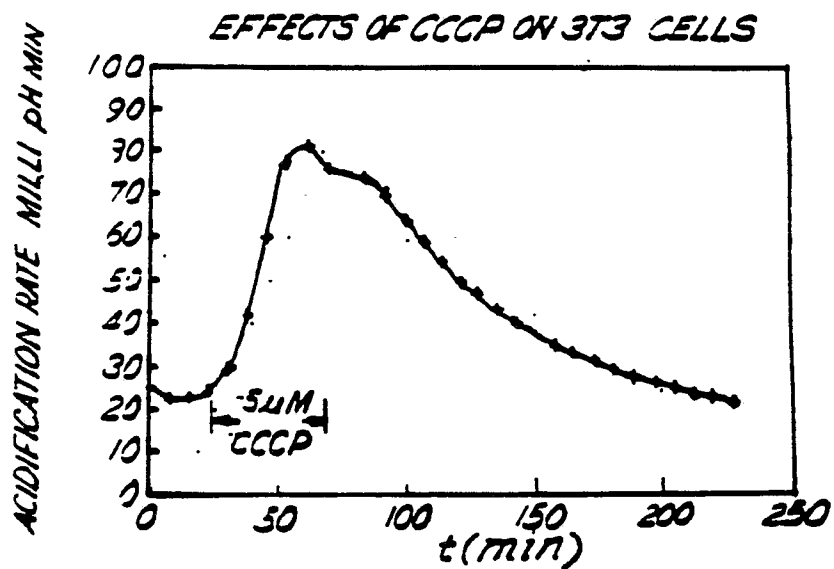
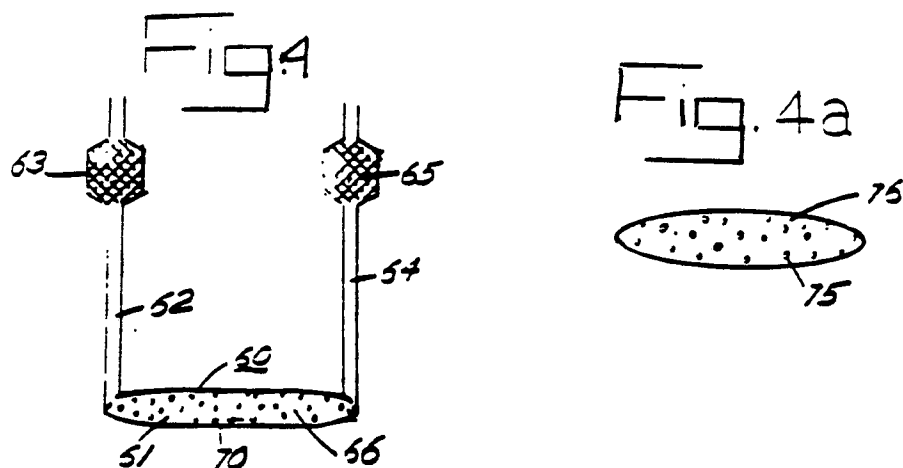


Fig. 5

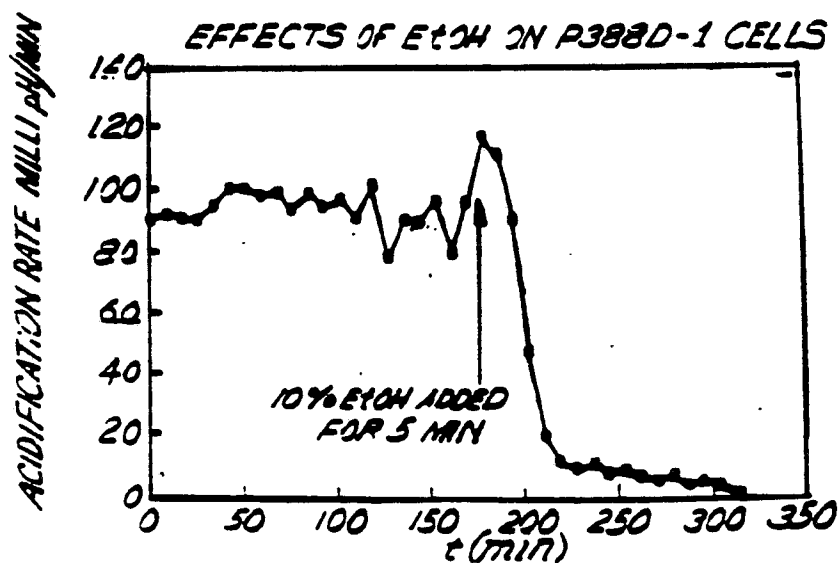


Fig. 6

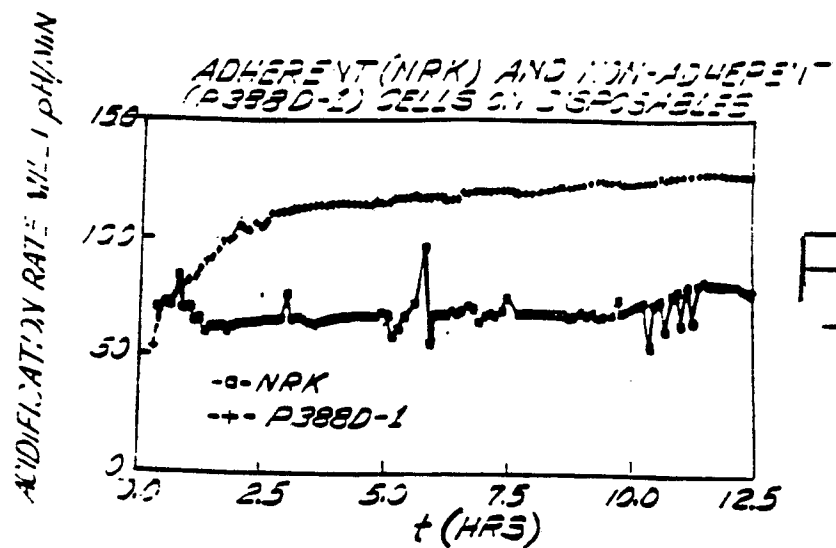


Fig. 7

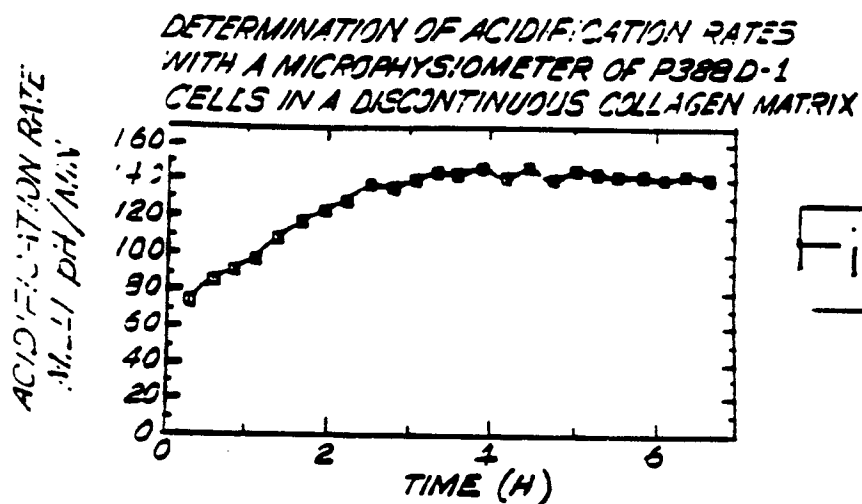


Fig. 8

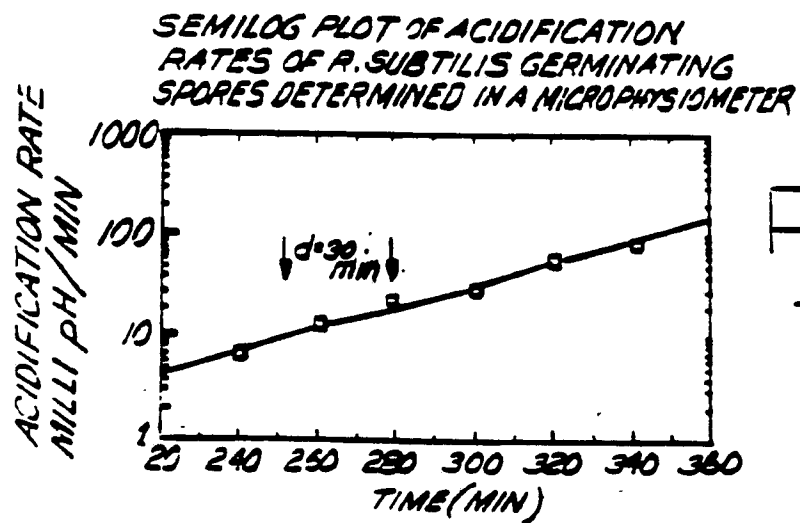


Fig. 9

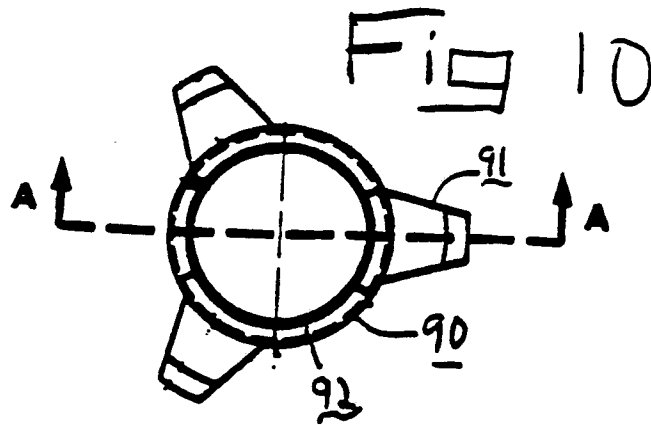


Fig 10a

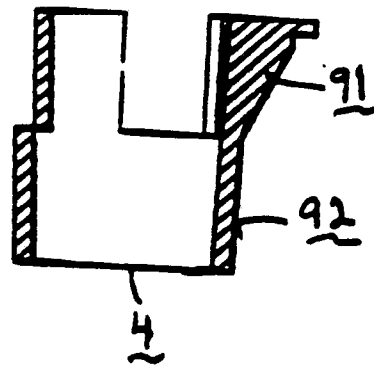


Fig 10b

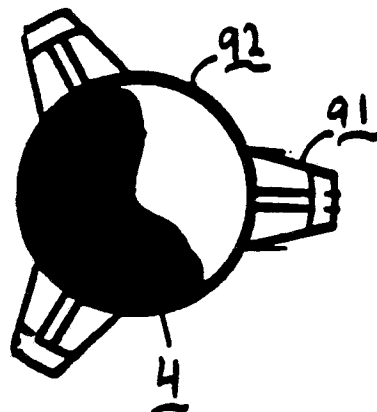
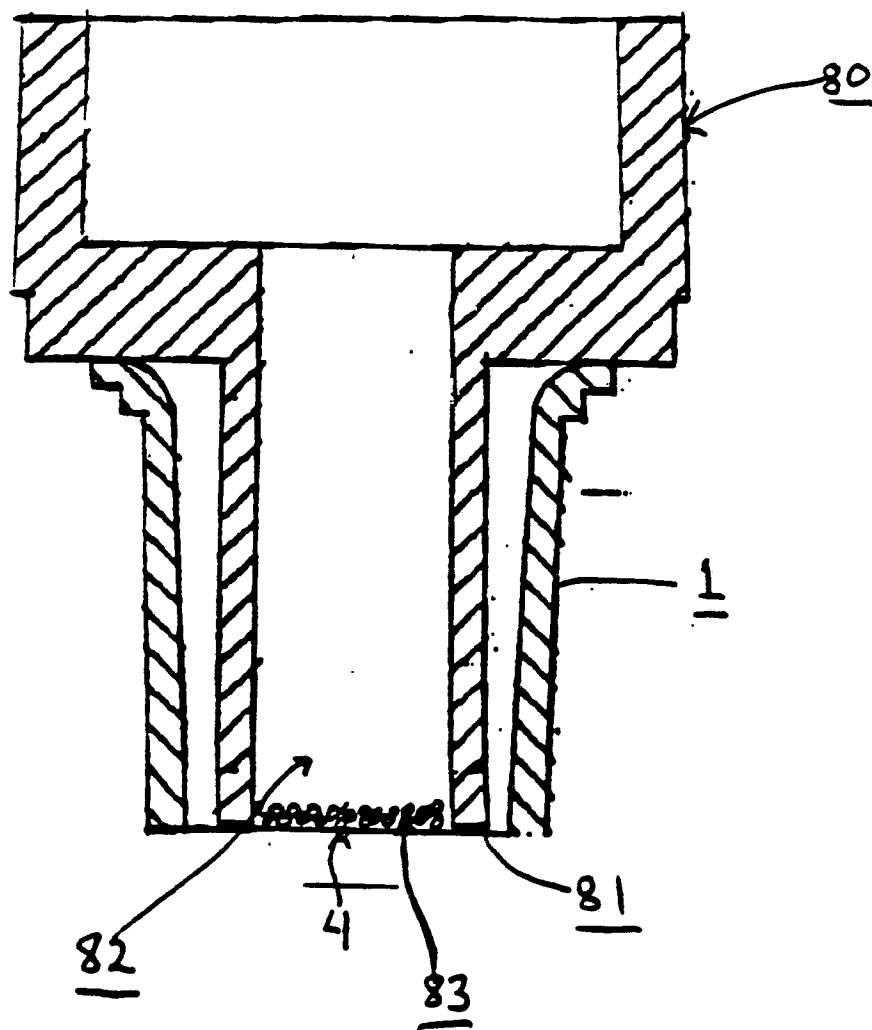


Fig 10c

Fig 11





## Figure 12

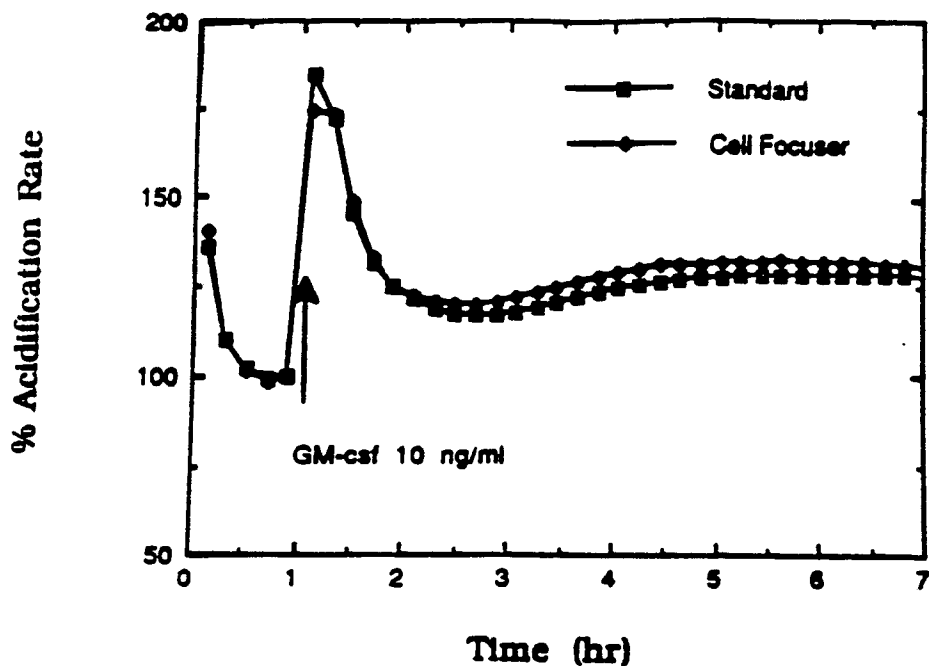
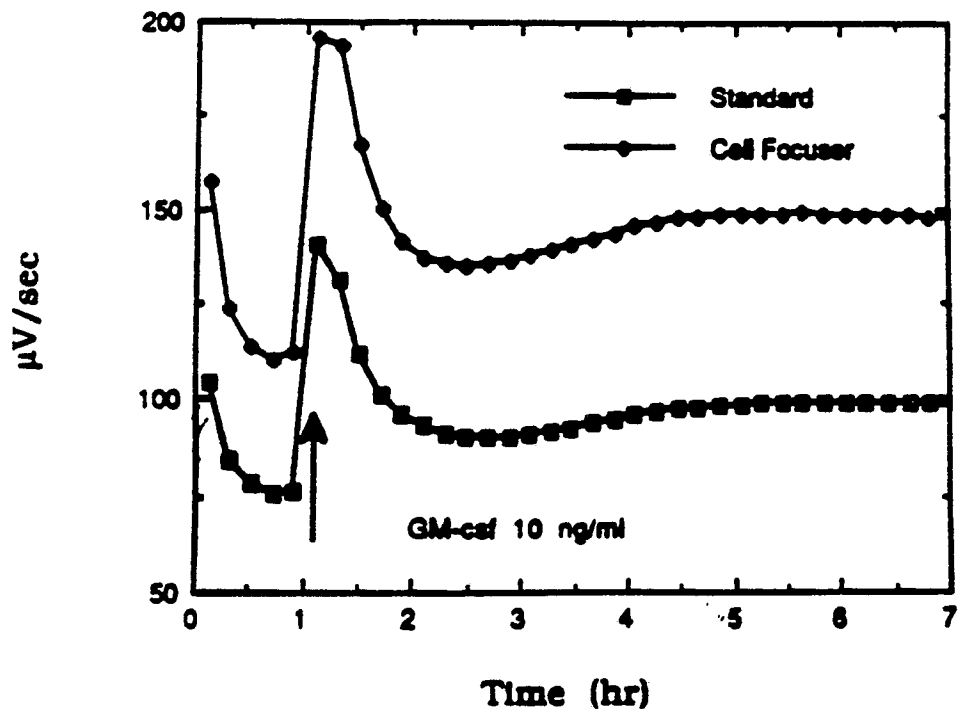
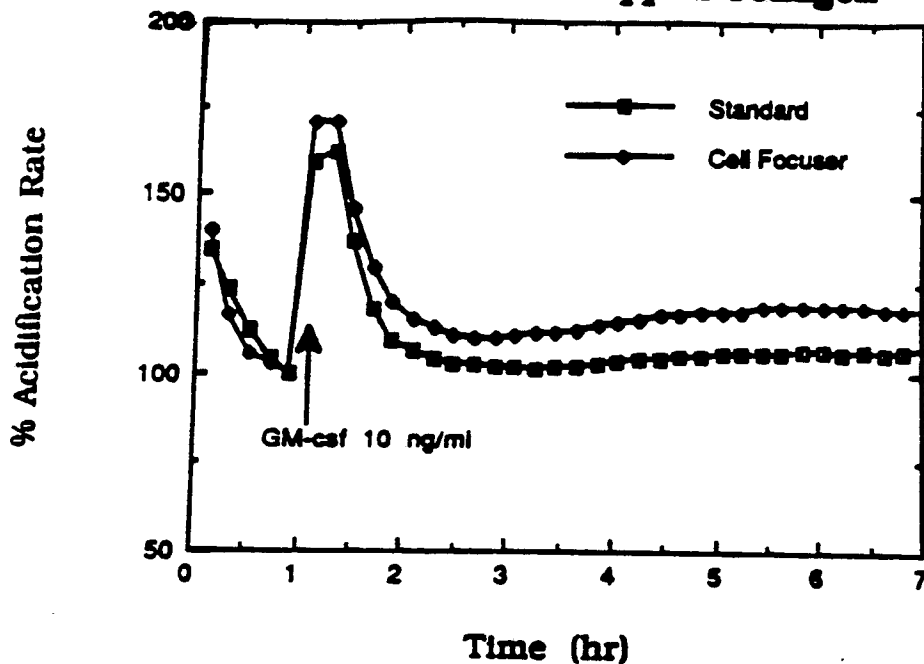
**Testing of Cell Focuser Using TF-1 Cells and GM-CSF Stimulation in Fibrin Gel****Testing of Cell Focuser Using TF-1 Cells and GM-CSF Stimulation in Fibrin Gel**

Figure 13

**Testing of Cell Focusers Using TF-1 Cells and GM-CSF Stimulation in Chopped Collagen****Testing of Cell Focusers Using TF-1 Cells and GM-CSF Stimulation in Chopped Collagen**